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Genta et al.

(10) **Patent No.: US 9,434,971 B2**
(45) **Date of Patent: Sep. 6, 2016**

(54) **SACCHARIDE-SOLUTION PRODUCING APPARATUS, FERMENTATION SYSTEM, SACCHARIDE-SOLUTION PRODUCING METHOD, AND FERMENTATION METHOD**

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(73) Assignee: **MITSUBISHI HEAVY INDUSTRIES MECHATRONICS SYSTEMS, LTD.**, Kobe-shi (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(22) PCT Filed: **Jan. 13, 2011**

(86) PCT No.: **PCT/JP2011/050448**
§ 371 (c)(1),
(2), (4) Date: **Aug. 9, 2012**

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PCT Pub. Date: **Jul. 19, 2012**

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C12P 19/02 (2006.01)
C12P 19/14 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***C12P 19/14*** (2013.01); ***C12M 21/12*** (2013.01); ***C12M 43/02*** (2013.01); ***C12M 45/02*** (2013.01); ***C12M 45/09*** (2013.01); ***C12M 45/20*** (2013.01);
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(58) **Field of Classification Search**
None
See application file for complete search history.

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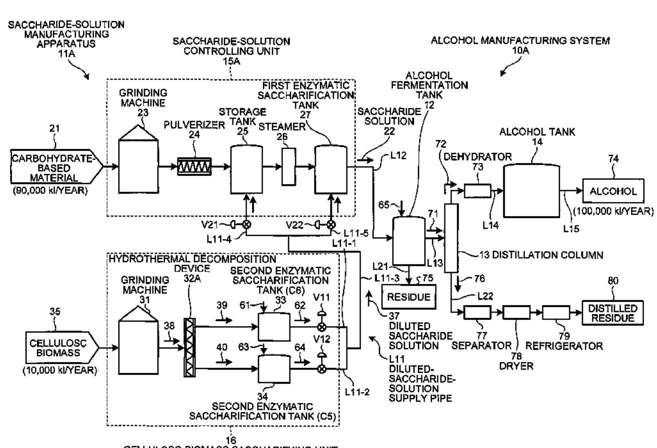
Primary Examiner — Thomas J Visone
(74) *Attorney, Agent, or Firm* — Westerman, Hattori, Daniels & Adrian, LLP

(57) **ABSTRACT**

A saccharide-solution producing apparatus **11**A according to the present invention is a saccharide-solution producing apparatus for producing a saccharide solution **22** derived from a carbohydrate-based material **21**, and includes a saccharide-solution controlling unit **15**A that controls the saccharide solution derived from the carbohydrate-based material **21**, a cellulosic biomass saccharifying unit **16** that saccharifies hydrothermally treated biomass obtained by hydrothermally decomposing a cellulosic biomass material **35** that contains a lignin component and a hemicellulose component, and produces a diluted saccharide solution **37**, and a diluted-saccharide-solution supply pipe L**11** that mixes the diluted saccharide solution **37** produced by the cellulosic biomass saccharifying unit **16** into the saccharide-solution controlling unit **15**A. With this configuration, it is possible to improve production efficiency of the saccharide solution **22** and to realize cost reduction.

3 Claims, 6 Drawing Sheets



(51) **Int. Cl.**

C13K 1/02	(2006.01)
C12P 7/10	(2006.01)
C12M 1/00	(2006.01)
C12M 1/33	(2006.01)

(52) **U.S. Cl.**

CPC ***C12P 7/10*** (2013.01); ***C12P 19/02*** (2013.01); ***C13K 1/02*** (2013.01); *C12P 2201/00* (2013.01); *C12P 2203/00* (2013.01); *Y02E 50/16* (2013.01); *Y02T 50/678* (2013.01)

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Non-Final Office Action dated Apr. 18, 2016, issued in U.S. Appl. No. 13/722,385 (31 pages).

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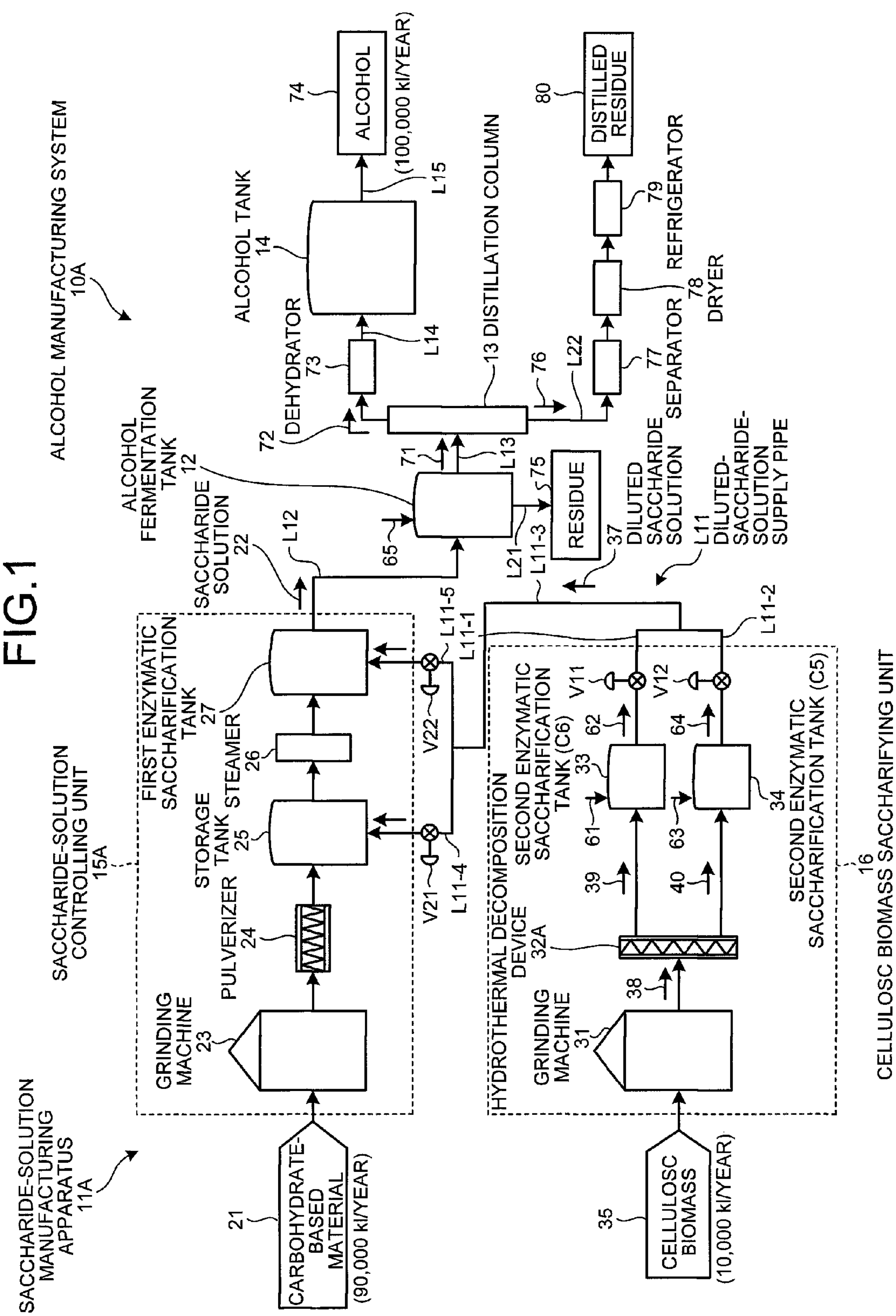
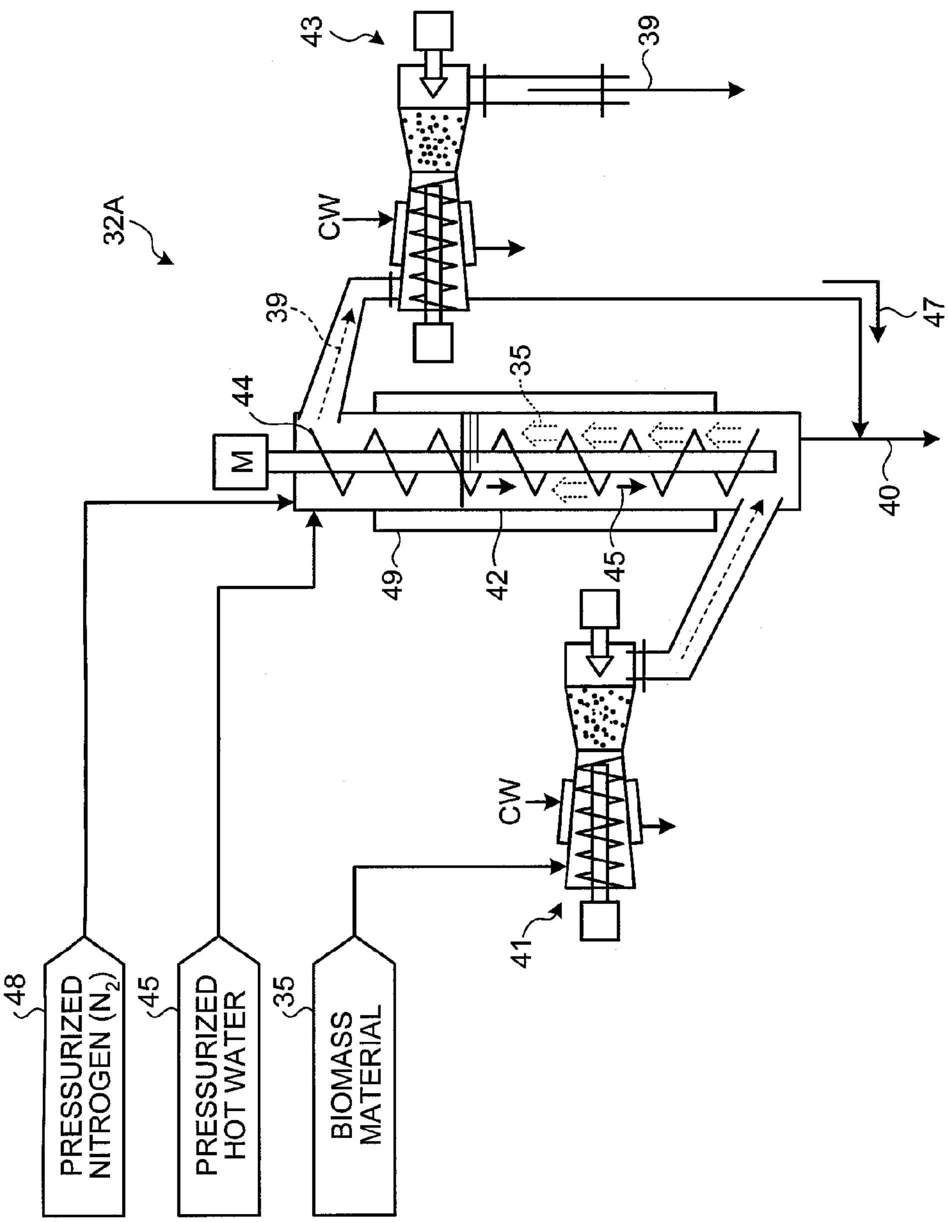
FIG.1



ALCOHOL MANUFACTURING SYSTEM
10A
SACCHARIDE-SOLUTION MANUFACTURING APPARATUS
11A
SACCHARIDE-SOLUTION CONTROLLING UNIT
15A
21
CARBOHYDRATE-BASED MATERIAL
(90,000 kl/YEAR)
GRINDING MACHINE
23
PULVERIZER
24
STORAGE TANK
25
STEAMER
26
FIRST ENZYMATIC SACCHARIFICATION TANK
27
V21
L11-4
V22
L11-5
L11-1
SACCHARIDE SOLUTION
22
L12
65
ALCOHOL FERMENTATION TANK
12
71
L13
75
RESIDUE
L21
L11-3
37
DILUTED SACCHARIDE SOLUTION
L11
DILUTED-SACCHARIDE-SOLUTION SUPPLY PIPE
L11-2
72
DEHYDRATOR
73
13 DISTILLATION COLUMN
L14
ALCOHOL TANK
14
L15
74
ALCOHOL
(100,000 kl/YEAR)
76
L22
77
SEPARATOR
78
DRYER
79
REFRIGERATOR
80
DISTILLED RESIDUE
35
CELLULOSC BIOMASS
(10,000 kl/YEAR)
GRINDING MACHINE
31
38
HYDROTHERMAL DECOMPOSITION DEVICE
32A
39
40
61
SECOND ENZYMATIC SACCHARIFICATION TANK (C6)
33
62
V11
63
34
SECOND ENZYMATIC SACCHARIFICATION TANK (C5)
64
V12
16
CELLULOSC BIOMASS SACCHARIFYING UNIT

FIG.2


32A
43
39
CW
47
35
44
M
40
45
42
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CW
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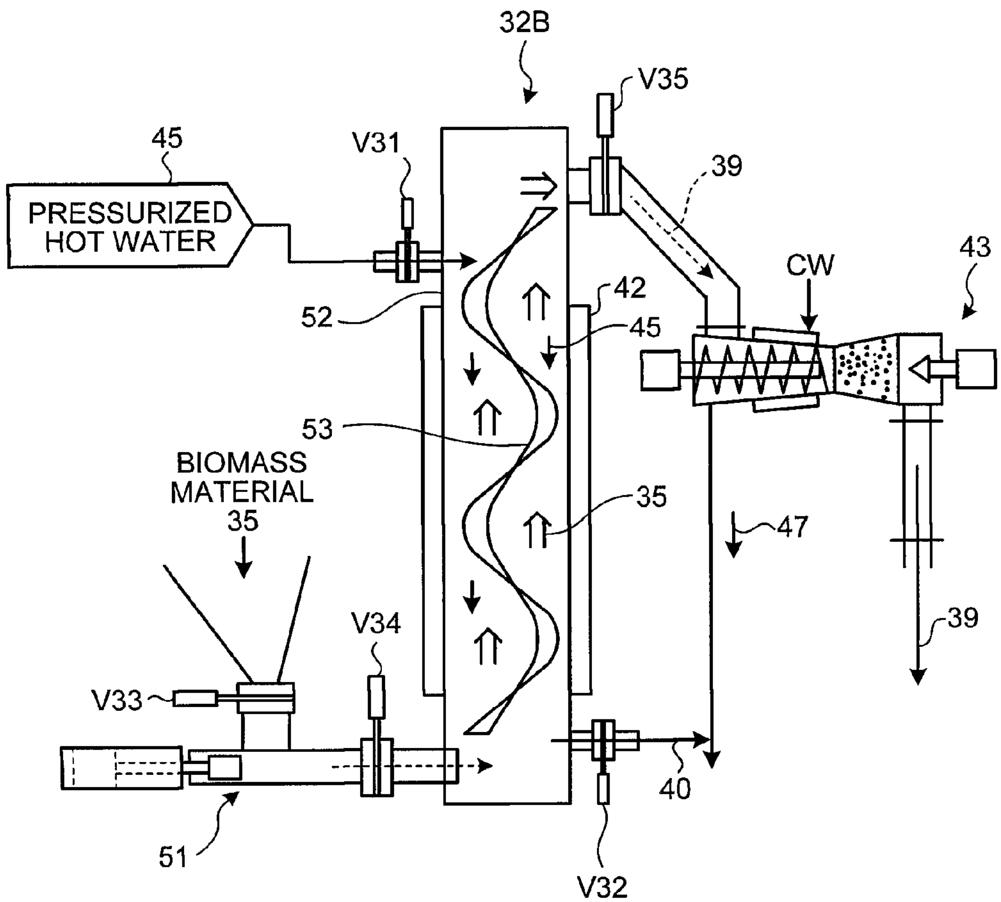
PRESSURIZED NITROGEN (N_2)
45
PRESSURIZED HOT WATER
35
BIOMASS MATERIAL

FIG.3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BIOMASS
MATERIAL
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47
39
V34
V33
40
51
V32

FIG.4

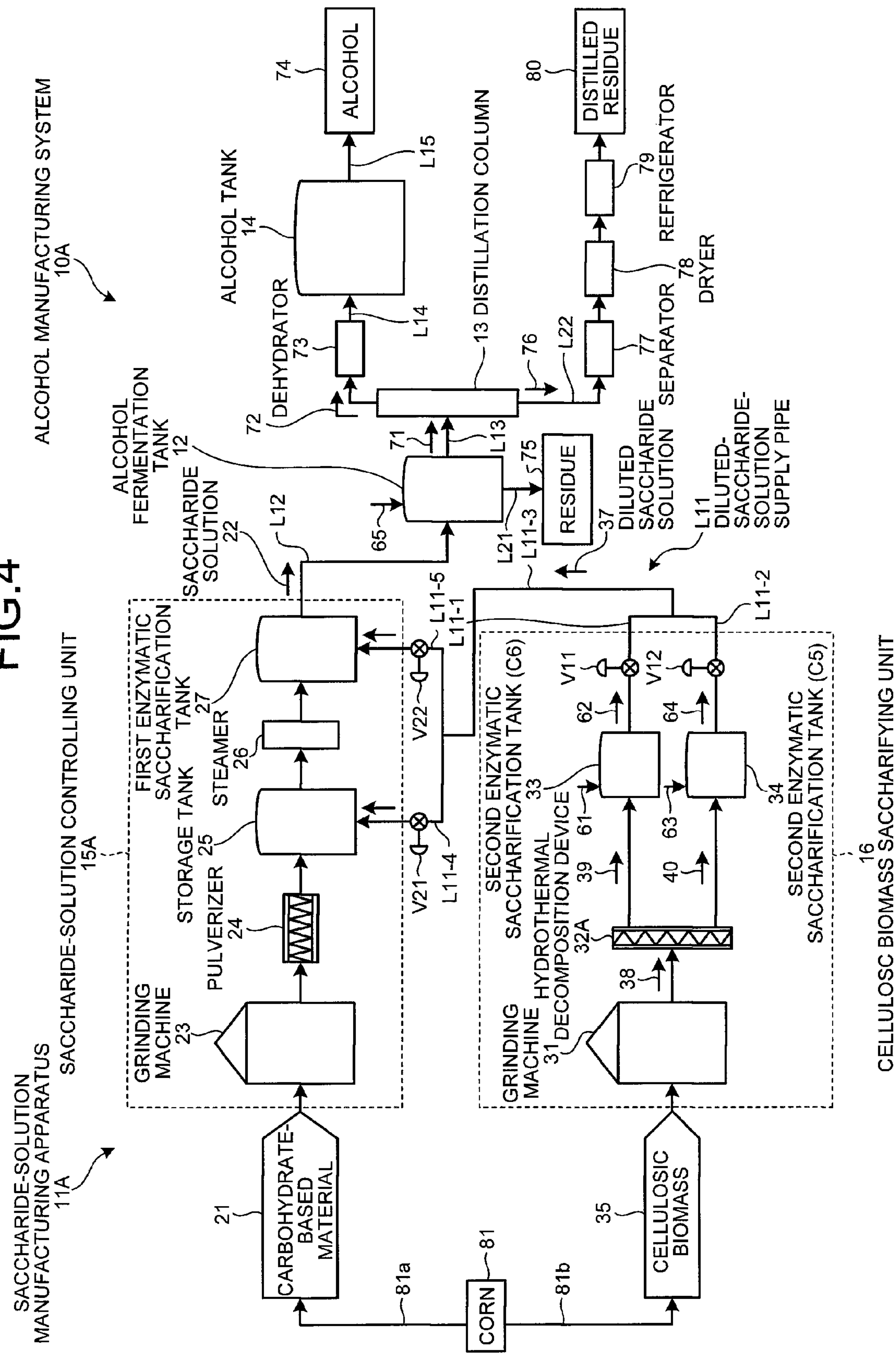
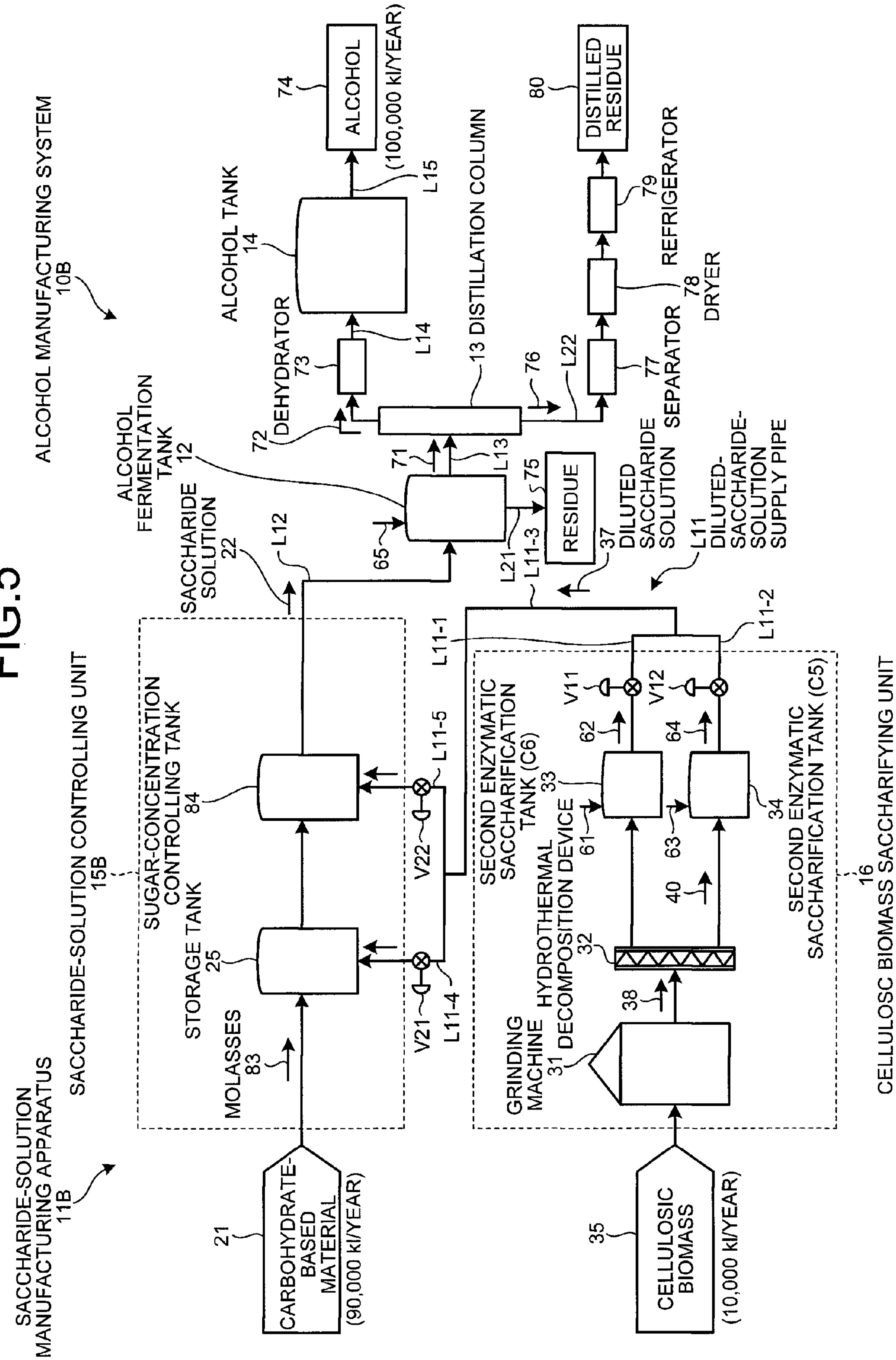

ALCOHOL MANUFACTURING SYSTEM
10A
SACCHARIDE-SOLUTION MANUFACTURING APPARATUS
11A
SACCHARIDE-SOLUTION CONTROLLING UNIT
15A
CELLULOSC BIOMASS SACCHARIFYING UNIT
16
CORN
81
81a
81b
CARBOHYDRATE-BASED MATERIAL
21
CELLULOSIC BIOMASS
35
GRINDING MACHINE
23
PULVERIZER
24
STORAGE TANK
25
STEAMER
26
FIRST ENZYMATIC SACCHARIFICATION TANK
27
SACCHARIDE SOLUTION
22
L12
GRINDING MACHINE
31
HYDROTHERMAL DECOMPOSITION DEVICE
32A
38
39
40
SECOND ENZYMATIC SACCHARIFICATION TANK (C6)
33
SECOND ENZYMATIC SACCHARIFICATION TANK (C5)
34
61
62
63
64
V11
V12
V21
V22
L11-1
L11-2
L11-3
L11-4
L11-5
L11
DILUTED-SACCHARIDE-SOLUTION SUPPLY PIPE
37
DILUTED SACCHARIDE SOLUTION
ALCOHOL FERMENTATION TANK
12
65
L21
RESIDUE
75
71
L13
72
13 DISTILLATION COLUMN
DEHYDRATOR
73
L14
ALCOHOL TANK
14
L15
ALCOHOL
74
76
L22
SEPARATOR
77
DRYER
78
REFRIGERATOR
79
DISTILLED RESIDUE
80

FIG.5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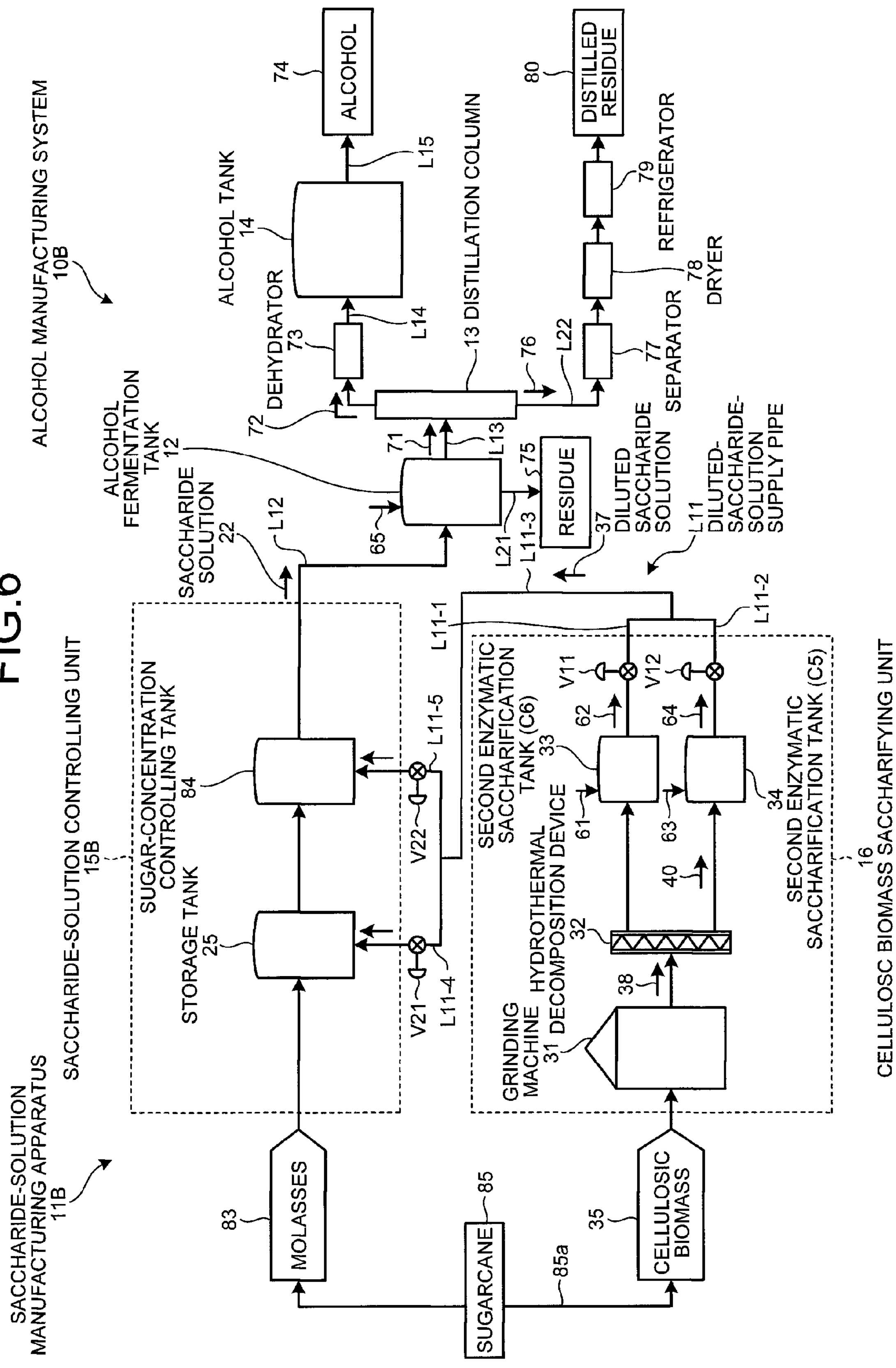
SACCHARIDE-SOLUTION CONTROLLING UNIT 15B
ALCOHOL MANUFACTURING SYSTEM 10B
21 CARBOHYDRATE-BASED MATERIAL (90,000 kl/YEAR)
MOLASSES 83
STORAGE TANK 25
SUGAR-CONCENTRATION CONTROLLING TANK 84
V21
L11-4
V22
L11-5
SACCHARIDE SOLUTION 22
L12
65
ALCOHOL FERMENTATION TANK 12
71
L13
L21
L11-3
RESIDUE
75
72
DEHYDRATOR 73
L14
ALCOHOL TANK 14
L15
74 ALCOHOL
(100,000 kl/YEAR)
13 DISTILLATION COLUMN
76
L22
77 SEPARATOR
78 DRYER
79 REFRIGERATOR
80 DISTILLED RESIDUE
37 DILUTED SACCHARIDE SOLUTION
L11 DILUTED-SACCHARIDE-SOLUTION SUPPLY PIPE
L11-1
L11-2
V11
V12
62
64
SECOND ENZYMATIC SACCHARIFICATION TANK (C6) 33
SECOND ENZYMATIC SACCHARIFICATION TANK (C5) 34
61
63
40
HYDROTHERMAL DECOMPOSITION DEVICE 32
38
GRINDING MACHINE 31
16
CELLULOSC BIOMASS SACCHARIFYING UNIT
35 CELLULOSIC BIOMASS (10,000 kl/YEAR)

FIG.6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SACCHARIDE-SOLUTION CONTROLLING UNIT 15B
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85a
MOLASSES
83
CELLULOSIC BIOMASS
35
STORAGE TANK
25
SUGAR-CONCENTRATION CONTROLLING TANK
84
V21
L11-4
V22
L11-5
SACCHARIDE SOLUTION
22
L12
65
ALCOHOL FERMENTATION TANK
12
71
L13
13 DISTILLATION COLUMN
72
DEHYDRATOR
73
L14
ALCOHOL TANK
14
L15
ALCOHOL
74
75
RESIDUE
L21
76
L22
77
SEPARATOR
78
DRYER
79
REFRIGERATOR
DISTILLED RESIDUE
80
L11-3
37
DILUTED SACCHARIDE SOLUTION
L11
DILUTED-SACCHARIDE-SOLUTION SUPPLY PIPE
L11-1
L11-2
GRINDING MACHINE
31
38
HYDROTHERMAL DECOMPOSITION DEVICE
32
40
61
63
SECOND ENZYMATIC SACCHARIFICATION TANK (C6)
33
SECOND ENZYMATIC SACCHARIFICATION TANK (C5)
34
62
64
V11
V12
16
CELLULOSC BIOMASS SACCHARIFYING UNIT

SACCHARIDE-SOLUTION PRODUCING APPARATUS, FERMENTATION SYSTEM, SACCHARIDE-SOLUTION PRODUCING METHOD, AND FERMENTATION METHOD

FIELD

The present invention relates to a saccharide-solution producing apparatus, a fermentation system, a saccharide-solution producing method, and a fermentation method for producing a saccharide solution derived from a carbohydrate-based material, and more particularly to improvement in saccharide-solution production efficiency when a saccharide solution is produced from a carbohydrate-based material.

BACKGROUND

Biomass that is organic resources of biological origin is produced by living organisms from water and carbon dioxide by the use of solar energy, and is sustainable and renewable resources. In recent years, as a part of global warming countermeasures, attempts have been extensively made to produce ethanol from biomass that contains a cellulosic material such as woody biomass or herbaceous biomass, and to use the ethanol as various types of fuel or chemical materials. Biomass ethanol produced from the biomass is a renewable natural energy, and the amount of carbon dioxide released into the condition does not increase even if the biomass ethanol is burned. From these perspectives, biomass is attracting attention as available and effective resources and is expected to be used as future energy sources.

The biomass is a collection of living organisms incorporated into the material circulation system in the earth's biosphere or a collection of organic matters derived from the living organisms (see JIS K 3600 1258). For example, the biomass is classified into a forest/woodland type (lumber scraps, lumber from thinning, paper waste and the like), an agricultural type (rice straw, wheat straw, sugarcane residues, rice bran, palm shell, plants and the like), an animal type (domestic animal waste and the like), a fishery type (fish processing residues and the like), and a waste type (left-over food products, garden plants, construction waste, sewerage sludge and the like).

Conventionally, as an ethanol producing method, there is used an ethanol producing method that includes saccharifying biomass or the like that contains a carbohydrate-based material, a cellulosic material or the like to produce a saccharide solution, and fermenting the obtained saccharide solution, thereby producing ethanol. For example, as an ethanol producing method using biomass, the following methods are proposed: an ethanol producing method that includes hydrolyzing collected biomass into saccharides by the addition of sulfuric acid, performing thereafter solid-liquid separation, neutralizing a liquid phase, subjecting the neutralized liquid phase to ethanol fermentation using microorganism such as yeast, and converting the liquid phase into ethanol (see Patent Literatures 1 and 2); and an ethanol producing method that includes performing hydrothermal decomposition by causing collected biomass and pressurized hot water to contact each other in a consolidated condition, thereby obtaining hydrothermally treated biomass, adding enzyme to the obtained hydrothermally treated biomass and saccharifying the obtained hydrothermally treated biomass, thereby obtaining a saccharide solution, and fermenting the obtained saccharide solution, thereby producing ethanol (see Patent Literatures 3 and 4).

CITATION LIST

Patent Literatures

Patent Literature 1: Japanese Patent Application National Publication No. H9-507386

Patent Literature 2: Japanese Patent Application National Publication No. H11-506934

Patent Literature 3: Japanese Patent Application Laid-open No. 2010-29862

Patent Literature 4: Japanese Patent Application Laid-open No. 2010-82620

SUMMARY

Technical Problem

In this case, it is required to ensure a high saccharide recovery ratio and to increase the saccharide concentration of the produced saccharide solution when enzyme is added to the hydrothermally treated biomass obtained from the biomass, in order to saccharify the hydrothermally treated biomass by the method of hydrothermally decomposing the biomass using the pressurized hot water as described in Patent Literatures 3 and 4. Therefore, it is necessary to increase the concentration of the hydrothermally treated biomass that serves as a material when saccharifying the hydrothermally treated biomass by the addition of the enzyme so as to produce the saccharide solution having a high saccharide concentration.

However, when the concentration of the hydrothermally treated biomass increases, there is a problem that the saccharide recovery ratio falls for such a reason as a worse mixed state between the hydrothermally treated biomass and the enzyme.

Furthermore, when the concentration of the hydrothermally treated biomass is high, the power requirement to agitate the hydrothermally treated biomass becomes high in an enzymatic saccharification tank that contains the hydrothermally treated biomass. As a result, there is a problem that power consumption necessary to produce the saccharide solution from the hydrothermally treated biomass increases.

Further, a method of excessively adding enzyme to hydrothermally treated biomass is considered so as to improve the saccharide recovery ratio in a state where the concentration of the hydrothermally treated biomass is high. However, the unit price of the enzyme used to saccharify the hydrothermally treated biomass is high. As a result, when the additive amount of the enzyme by which the enzyme is added to the hydrothermally treated biomass increases, there is a problem that the cost required to produce ethanol rises.

Generally, therefore, a concentration operation such as evaporation concentration is performed so as to obtain a predetermined concentration suited for fermentation for causing, for example, alcohol fermentation after saccharifying the hydrothermally treated biomass.

On the other hand, when various organic materials are produced from a saccharide solution derived from the carbohydrate-based material (obtained by saccharification, extraction, or squeezing), an alcohol fermentation system including a saccharide-solution producing apparatus, for example, is put in a higher alcohol concentration condition as fermentation proceeds and microorganism that cause fermentation become extinct when the concentration of the saccharide solution used for the fermentation is high. Therefore, it is necessary to dilute the saccharide solution (at the saccharide concentration of about 20% to 60%) with water and to control the saccharide concentration.

Therefore, under these circumstances, there has been a demand for an efficient system capable of solving the problems that occur when saccharides are produced by the biomass treatment mentioned above and when various organic materials are produced from the saccharide solution derived from the carbohydrate-based material.

In view of the above problems, an object of the present invention is to provide a saccharide-solution producing apparatus, a fermentation system, a saccharide-solution producing method, and a fermentation method capable of improving saccharide-solution production efficiency and realizing cost reduction.

Solution to Problem

According to an aspect of the present invention, a saccharide-solution producing apparatus for producing a saccharide solution derived from a carbohydrate-based material includes: a saccharide-solution controlling unit that controls the saccharide concentration derived from the carbohydrate-based material; a cellulosic biomass saccharifying unit that saccharifies hydrothermally treated biomass obtained by hydrothermally decomposing a cellulosic biomass material containing a lignin component and a hemicellulose component to produce a diluted saccharide solution; and a diluted-saccharide-solution supply pipe that mixes a diluted saccharide solution produced by the cellulosic biomass saccharifying unit into the saccharide-solution controlling unit.

Advantageously, in the saccharide-solution producing apparatus, the saccharide solution is obtained by saccharifying the carbohydrate-based material or is discharged or squeezed from the carbohydrate-based material.

Advantageously, in the saccharide-solution producing apparatus, the cellulosic biomass saccharifying unit includes a hydrothermal decomposition device that hydrothermally treats the cellulosic biomass material and to produce hydrothermally treated biomass, and a second enzymatic saccharification tank that adds enzyme to the hydrothermally treated biomass to saccharify the hydrothermally treated biomass, and generates the diluted saccharide solution.

Advantageously, in the saccharide-solution producing apparatus, the hydrothermal decomposition device hydrothermally decomposes the cellulosic biomass material while causing the cellulosic biomass material to contact pressurized hot water, transfers a lignin component and a hemicellulose component into the pressurized hot water, and separates the lignin component and the hemicellulose component from the cellulosic biomass material, and a hydrothermally discharged fraction that contains the lignin component and the hemicellulose component and a solid residual fraction that contains a cellulose component are produced as the hydrothermally treated biomass.

Advantageously, in the saccharide-solution producing apparatus, the second enzymatic saccharification tank produces one of or both of a diluted saccharide solution that contains hexose by adding enzyme to the solid residual fraction discharged from the hydrothermal decomposition device and enzymatically decomposing a cellulose component contained in the solid residual fraction, and a diluted saccharide solution that contains pentose by adding enzyme to the hydrothermally discharged fraction discharged from the hydrothermal decomposition device and enzymatically decomposing a hemicellulose component contained in the hydrothermally discharged fraction.

Advantageously, in the saccharide-solution producing apparatus, a saccharide concentration of the diluted saccharide solution is equal to or higher than 0.1 mass % and equal to or lower than 15 mass %.

According to another aspect of the present invention, a fermentation system includes: the saccharide-solution producing apparatus according to any one of above; and an alcohol fermentation tank that ferments the saccharide solution to produce an organic material.

According to still another aspect of the present invention, a saccharide-solution producing method for producing a saccharide solution derived from a carbohydrate-based material includes: producing hydrothermally treated biomass by hydrothermally decomposing a cellulosic biomass material containing a lignin component and a hemicellulose component, saccharifying the hydrothermally treated biomass by adding enzyme to the obtained hydrothermally treated biomass to produce a diluted saccharide solution; and producing the saccharide solution derived from the carbohydrate-based material by using the diluted saccharide solution when the saccharide solution is controlled.

Advantageously, in the saccharide-solution producing method, as the saccharide solution, a saccharide solution obtained by saccharifying the carbohydrate-based material or a saccharide solution discharged or squeezed from the carbohydrate-based material is used.

Advantageously, in the saccharide-solution producing method includes: hydrothermally decomposing the cellulosic biomass material while causing the cellulosic biomass material to contact pressurized hot water; transferring a lignin component and a hemicellulose component into the pressurized hot water; separating the lignin component and the hemicellulose component from the cellulosic biomass material; and producing a hydrothermally discharged fraction that contains the lignin component and the hemicellulose component, and a solid residual fraction that contains a biomass solid content. One of or both of the hydrothermally discharged fraction and the solid residual fraction is used as the hydrothermally treated biomass.

Advantageously, in the saccharide-solution producing method, one of or both of a diluted saccharide solution that contains hexose and that is obtained by adding enzyme to the solid residual fraction and by enzymatically decomposing a cellulose component contained in the solid residual fraction, and a diluted saccharide solution that contains pentose and that is obtained by adding enzyme to the hydrothermally discharged fraction and by enzymatically decomposing the hemicellulose component contained in the hydrothermally discharged fraction is used as the diluted saccharide solution.

Advantageously, in the saccharide-solution producing method, a saccharide concentration of the diluted saccharide solution is set equal to or higher than 0.1 mass % and equal to or lower than 15 mass %.

According to still another aspect of the present invention, a fermentation method comprising any one of the saccharide-solution producing methods described above. A saccharide solution obtained by using the saccharide-solution producing method is fermented to produce an organic material.

In addition, to solve the above problems, the following configurations can be employed.

(1) That is, the saccharide-solution producing apparatus can be configured such that, when the saccharide solution is obtained by saccharifying the carbohydrate-based material, the saccharide-solution controlling unit includes a storage

tank that stores therein the carbohydrate-based material, and a first enzymatic saccharification tank for enzymatically saccharifying the carbohydrate-based material.

(2) The saccharide-solution producing apparatus can be configured such that, when the saccharide solution is discharged or squeezed from the carbohydrate-based material, the saccharide-solution controlling unit includes a storage tank that stores therein the carbohydrate-based material, and a saccharide-concentration controlling tank.

(3) The saccharide-solution producing method can include adding the saccharide solution to one of or both of a storage tank that stores therein the carbohydrate-based material and a first enzymatic saccharification tank for enzymatically saccharifying the carbohydrate-based material when the saccharide solution is obtained by saccharifying the carbohydrate-based material.

(4) The saccharide-solution producing method can include adding the saccharide solution to one of or both of a storage tank that stores therein the carbohydrate-based material and a saccharide-concentration controlling tank when the saccharide solution is discharged or squeezed from the carbohydrate-based material.

Advantageous Effects of Invention

According to the present invention, saccharide-solution production efficiency can be improved and cost reduction can be realized.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a schematic diagram of an alcohol producing system including a saccharide-solution producing apparatus according to a first embodiment of the present invention.

FIG. **2** depicts a configuration of a hydrothermal decomposition device.

FIG. **3** is a conceptual diagram of another configuration of the hydrothermal decomposition device.

FIG. **4** is an example of a case where corns are applied as a material.

FIG. **5** is a schematic diagram of an alcohol producing system including a saccharide-solution producing apparatus according to a second embodiment of the present invention.

FIG. **6** is an example of a case where sugarcane is applied as a material.

DESCRIPTION OF EMBODIMENTS

Exemplary embodiments of the present invention will be explained below in detail with reference to the accompanying drawings. The present invention is not limited to the contents of the embodiments described below. In addition, constituent elements described below include elements that can be easily assumed by persons skilled in the art, elements that are substantially identical, and so-called equivalents. Furthermore, it is possible to carry out appropriate combinations of the constituent elements described below.

First Embodiment

A saccharide-solution producing apparatus according to a first embodiment of the present invention is described with reference to the drawings. FIG. **1** is a schematic diagram of an alcohol producing system including the saccharide-solution producing apparatus according to the first embodiment of the present invention. As shown in FIG. **1**, an alcohol producing system **10**A includes a saccharide-solution producing apparatus **11**A according to the present embodiment, an alcohol fermentation tank **12**, a distillation column **13**, and an alcohol tank **14**.

The saccharide-solution producing apparatus **11**A according to the present embodiment includes a saccharide-solution controlling unit **15**A and a cellulosic biomass saccharifying unit **16**.

(Saccharide-Solution Controlling Unit)

The saccharide-solution controlling unit **15**A produces a saccharide solution **22** from a carbohydrate-based material **21**. The saccharide-solution controlling unit **15**A includes a grinding machine **23**, a pulverizer **24**, a storage tank **25**, a cooker **26**, and a first enzymatic saccharification tank **27**. The carbohydrate-based material **21** is ground by the grinding machine **23** and further pulverized by the pulverizer **24**. The pulverized carbohydrate-based material **21** is stored in the storage tank **25**. After the cooker **26** steams the carbohydrate-based material **21** stored in the storage tank **25**, a saccharide concentration of the carbohydrate-based material **21** stored in the storage tank **25** is controlled and the carbohydrate-based material **21** is saccharified in the first enzymatic saccharification tank **27**. In the present embodiment, a diluted saccharide solution **37**, to be described later, is added into one of or both of the storage tank **25** and the first enzymatic saccharification tank **27**, and is used as a diluted solution when the saccharide solution **22** is produced from the carbohydrate-based material **21**. As described later, by adding the diluted saccharide solution **37** into the storage tank **25**, the carbohydrate-based material **21** is diluted with the diluted saccharide solution **37**. The carbohydrate-based material **21** within the storage tank **25** can be thereby easily enzymatically saccharified in the first enzymatic saccharification tank **27** and can be easily transferred.

(Cellulosic Biomass Saccharifying Unit)

The cellulosic biomass saccharifying unit **16** includes a grinding machine **31**, a hydrothermal decomposition device **32**A, a second enzymatic saccharification tank (C**6**) **33**, and a second enzymatic saccharification tank (C**5**) **34**. The cellulosic biomass saccharifying unit **16** saccharifies hydrothermally treated biomass that is obtained by hydrothermally decomposing a cellulosic biomass material **35**, and produces the diluted saccharide solution **37**.

The biomass is not limited to a specific type but signifies a collection of living organisms incorporated into the material circulation system in the earth's biosphere or a collection of organic matters derived from the living organisms (see JIS K 3600 1258). As the biomass, for example, it is preferable to use, particularly woody biomass, broadleaf trees, ligno-cellulose resources as herbaceous biomass, agricultural waste, left-over food products or the like. In the present embodiment, for example, the cellulosic biomass material **35** is rice straw, wheat straw, corn stover (corn stalks), corncobs (corn cobs), or EFB (empty fruit bunch of oil palms). However, the present embodiment is not limited thereto.

The cellulosic biomass material **35** is ground into a ground biomass material **38** of 5 millimeters or less, for example, by the grinding machine **31**. The ground biomass material **38** is hydrothermally treated by the hydrothermal decomposition device **32**A. The hydrothermal decomposition device **32**A hydrothermally decomposes the ground biomass material **38** while causing the ground biomass material **38** and pressurized hot water countercurrently contact with each other, transfers lignin components and hemicellulose components into the pressurized hot water, and separates the lignin components and the hemicellulose components from a biomass solid content. The hydrothermally treated biomass is obtained by hydrothermally treating the ground biomass material **38** in the hydrothermal decomposition device **32**A, and is separated into a solid residual fraction **39** that is the biomass solid content and a hydrothermally treated fraction **40** that is the lignin components and the hemicellulose components transferred into the pressurized hot water.

FIG. **2** depicts a configuration of the hydrothermal decomposition device **32**A. As shown in FIG. **2**, the hydrothermal decomposition device **32**A includes a biomass supply device **41**, a reaction device **42**, and a biomass discharge device **43**. The biomass supply device **41** supplies the cellulosic biomass material (hereinafter, "biomass material") **35** from under an normal pressure to under an increased pressure.

The reaction device **42** transports the supplied biomass material **35** from one side (a lower side in the present embodiment) to the other side (an upper side) within a device main body by a screw unit **44**, supplies pressurized hot water **45** into the device main body from the other side (the upper side) different from a portion from which the biomass material **35** is supplied, and hydrothermally decomposes the biomass material **35** while causing the biomass material **35** and the pressurized hot water **45** to countercurrently contact with each other. With this configuration, the lignin components and the hemicellulose components are transferred into the pressurized hot water **45**, separated from within the biomass material **35**, and discharged from the reaction device **42** as the hydrothermally discharged fraction **40**.

The biomass discharge device **43** extracts the solid residual fraction **39** that is the biomass solid content from the other side of the reaction device **42**. In FIG. **2**, reference sign **47** denotes a dehydration liquid, **48** denotes pressurized nitrogen (N_2), and **49** denotes a temperature jacket.

In the present embodiment, the biomass material **35** is supplied from a lower end side. However, the present embodiment is not limited thereto. The biomass material **35** can be alternatively and conversely supplied from an upper end side, in which case, the pressurized hot water **45** is supplied from the lower end side.

Examples of the biomass supply device **41** that supplies the biomass material **35** from under a normal pressure to under an increased pressure include units such as a screw feeder, a piston pump, and a slurry pump.

While the reaction device **42** is a vertical device in the present embodiment, the present embodiment is not limited thereto. Alternatively, an inclined reaction device or a horizontal reaction device can be used as the reaction device **42**. In this case, the reason for using the vertical or inclined type is that the vertical or inclined reaction device can promptly discharge gas generated in a hydrothermal decomposition reaction, gas brought into a material or the like from above, and is preferably used.

In the present embodiment, before biomass is supplied, the biomass is pretreated by the use of the grinding machine **31** that serves as a pretreatment device. However, the present invention is not limited thereto, and when a particle diameter of the biomass material **35** is sufficiently small, there is no need to provide the grinding machine **31**. Alternatively, a wet scrubber can wash the biomass material **35**. It is assumed that the biomass material **35** can be supplied directly to the reaction device **42** without pulverizing the biomass material **35** when the biomass material **35** is rice hulls, for example.

A reaction temperature in the reaction device **42** is preferably set to be equal to or higher than 180° C. and equal to or lower than 240° C., more preferably set to be equal to or higher than 200° C. and equal to or lower than 230° C. for the following reasons. That is, at a low temperature below 180° C., if the hydrothermal decomposition rate is low, a long decomposition time becomes necessary, and the size of the device has to be large. Therefore, the low temperature below 180° C. is not preferable. On the other hand, a temperature higher than 240° C. excessively increases the decomposition rate, increases transfer of cellulose components from a solid side to a liquid side, and promotes excessively decomposing hemicellulosic saccharides. Therefore, the temperature higher than 240° C. is not preferable. Furthermore, the hemicellulose components are dissolved at about 140° C. or higher, the cellulose components are dissolved at about 230° C. or higher, and the lignin components are dissolved at about 140° C. or higher. Therefore, the reaction temperature is preferably set within a range from 180° C. to 240° C. within which the hemicellulose components and the lignin components are decomposed at a sufficient decomposition rate.

The reaction pressure of the hydrothermal decomposition is preferably set to a pressure higher by 0.1 MPa to 0.5 MPa than the saturated vapor pressure of water at each temperature, which allows the pressurized hot water to stay inside the device.

The reaction time is preferably set to be equal to or shorter than 20 minutes, more preferably set to be equal to or higher than 3 minutes and equal to or lower than 10 minutes. This is because the ratio of an excessively decomposed material increases at a reaction time that is too long and it is not preferable.

In the present embodiment, it is preferable that flow of the pressurized hot water **45** and that of the biomass material **35** within the main body of the reaction device **42** are so-called counter flows for causing the biomass material **35** and the pressurized hot water **45** to countercurrently contact each other so that the biomass material **35** and the pressurized hot water **45** can contact each other, can be agitated, and can flow.

In the reaction device **42**, the solid content of the biomass material **35** is supplied from a bottom side, the pressurized hot water **45** is supplied from a top side, and the biomass material **35** and the pressurized hot water **45** contact each other and move, whereby the pressurized hot water (hot water, a liquid into which the decomposed material is dissolved) **45** moves while soaking between solid particles in a counter flow to the flow of the biomass material **35** that is the solid content.

In the present embodiment, the pressurized nitrogen (N_2) **48** is supplied into the reaction device **42** because a gaseous part is present within the reaction device **42**. However, the present invention is not limited thereto and the pressurized N_2 **48** is not necessarily supplied into the reaction device **42**.

It is possible to increase the temperature of the biomass material **35** in the reaction device **42** by allowing the biomass material **35** to contact the pressurized hot water **45** and to directly exchange heat with the pressurized hot water **45** in the reaction device **42**. The biomass material **35** can be heated from outside by using steam or the like as needed.

In the present embodiment, by causing the biomass material **35** and the pressurized hot water **45** to countercurrently contact each other, components easily soluble into the pressurized hot water **45** are sequentially discharged, and a temperature gradient occurs from an input part from which the biomass material **35** is input to a hot-water input part. This can suppress the hemicellulose components from being excessively decomposed and can eventually efficiently recover pentose components. Furthermore, by causing the biomass material **35** and the pressurized hot water **45** to countercurrently contact each other, heat recovery can be made, which is preferable in view of system efficiency.

The configuration of the hydrothermal decomposition device **32**A is not limited to that shown in FIG. **2**. FIG. **3** is a conceptual diagram of another configuration of the hydrothermal decomposition device. As shown in FIG. **3**, a biomass hydrothermal decomposition device **32**B according to the present embodiment includes a biomass supply device **51**, a reaction device **52**, and the biomass discharge device **43**. V**31** to V**35** denote differential pressure control valves (ON-OFF valves).

The biomass supply device **51** supplies the biomass material (such as wheat straw, in the present embodiment) **35** from under a normal pressure to under an increased pressure. Examples of the biomass supply device **51** include units such as a screw feeder, a piston pump, and a slurry pump.

The reaction device **52** gradually moves the supplied biomass material **35** from an upper or lower end side (a lower end side in the present embodiment) into a vertical device main body (hereinafter, "device main body") in a consolidated condition, and supplies the pressurized hot water **45** into the device main body from the end side (the upper end side in the present embodiment) different from the end side from which the biomass material **35** is supplied. In addition, the reaction device **52** hydrothermally decomposes the biomass material **35** while causing the biomass material **35** to countercurrently contact the pressurized hot water **45**, transfers the lignin components and the hemicellulose components into the pressurized hot water **45**, and separates the lignin components and the hemicellulose components from the biomass material **35**.

As described above, the biomass discharge device **43** discharges the solid residual fraction **39** that is the biomass solid content from the supply side of the pressurized hot water **45** of the device main body.

A fixed agitating unit **53** that agitates the biomass material **35** in a so-called consolidated condition of a plug flow is provided within the device main body. By rotation of the fixed agitating unit **53**, the biomass material **35** is agitated in response to an agitation action generated by the rotation of the fixed agitating unit **53** when the biomass material **35** fed into the device main body is moved in an axial direction. By providing the fixed agitating unit **53** within the device main body, mixing of the pressurized hot water **45** with a surface of the solid and an interior of the solid and the reaction is promoted in the device main body.

It is preferable that the flow of the pressurized hot water **45** and that of the biomass material **35** within the main body of the hydrothermal decomposition device **32**B are the so-called counter flows for causing the biomass material **35** and the pressurized hot water **45** to countercurrently contact each other so that the biomass material **35** and the pressurized hot water **45** can contact each other, can be agitated, and can flow with views of efficiently mixing the biomass material **35** with the pressurized hot water **45** and promoting the reaction.

The hydrothermal decomposition device **32**B hydrothermally decomposes the biomass material **35** by means of the plug flow. Therefore, the hydrothermal decomposition device **32**B is simple in structure and the biomass material **35** that is solid is moved in parallel to a central axis of a pipe while being agitated perpendicularly to be central axis of the pipe. On the other hand, the pressurized hot water **45** (hot water, a liquid into which the decomposed material is dissolved) moves while soaking in the solid particles in the counter flow to the flow of the solid.

Furthermore, the plug flow can realize the uniform flow of the pressurized hot water **45**. When the solid biomass material **35** is decomposed by the pressurized hot water **45**, the decomposed material is dissolved into the hot water. The viscosity is high near decomposed portions, hot water moves preferentially to near non-decomposed portions, and the non-decomposed portions are decomposed subsequently to the decomposed portions. This can create the uniform flow of the hot water and uniform decomposition.

The hydrothermal decomposition device **32**B includes the fixed agitating unit **53** within the device main body. Because of resistance of a pipe wall on an inside surface of the device main body of the hydrothermal decomposition device **32**B, a solid concentration of the biomass material **35** on an outlet side decreases as compared with that of the biomass material **35** on an inlet side, and the solid residual fraction **39** that is the biomass solid content decrease by decomposition. Accordingly, a ratio of the pressurized hot water **45** increase, and the decomposed components in the liquid are excessively decomposed as a result of an increase in a liquid residence time. Therefore, by providing at least the fixed agitating unit **53** within the device main body, the hydrothermal decomposition device **32**B can suppress the ratio of the pressurized hot water **45** and reduce the liquid residence time, thereby making it possible to suppress the decomposed components in the liquid from being excessively decomposed.

As shown in FIG. **1**, in the saccharide-solution producing apparatus **11**A according to the present embodiment, the solid residual fraction **39** and the hydrothermally discharged fraction **40** are discharged from the hydrothermal decomposition device **32**A as the hydrothermally treated biomass. The solid residual fraction **39** in the hydrothermally treated biomass is supplied to the second enzymatic saccharification tank (C**6**) **33**, and the hydrothermally discharged fraction **40** is supplied to the second enzymatic saccharification tank (C**5**) **34**.

The second enzymatic saccharification tank (C**6**) **33** performs an enzymatic treatment on cellulose contained in the solid residual fraction **39** discharged from the hydrothermal decomposition device **32**A with first enzyme (cellulase) **61**, thereby obtaining a first saccharide solution **62** containing hexose.

The second enzymatic saccharification tank (C**5**) **34** performs an enzymatic treatment on the hemicellulose components transferred into the hydrothermally discharged fraction **40** discharged from the hydrothermal decomposition device **32**A with second enzyme **63**, thereby obtaining a second saccharide solution **64** containing pentose.

One of or both of the first saccharide solution **62** obtained in the second enzymatic saccharification tank (C**6**) **33** and the second saccharide solution **64** obtained in the second enzymatic saccharification tank (C**5**) **34** is used as the diluted saccharide solution **37**. As described above, this diluted saccharide solution **37** is supplied to one of or both of the storage tank **25** and the first enzymatic saccharification tank **27** via a diluted-saccharide-solution supply pipe L**11**.

The diluted-saccharide-solution supply pipe L**11** includes a diluted-saccharide-solution supply pipe L**11-1** connected to the second enzymatic saccharification tank (C**6**) **33**, a diluted-saccharide-solution supply pipe L**11-2** connected to the second enzymatic saccharification tank (C**5**) **34**, a diluted-saccharide-solution supply pipe L**11-3** that supplies the diluted saccharide solution **37** to the saccharide-solution controlling unit 15A from a portion in which the diluted-saccharide-solution supply pipe L11-1 is connected to the diluted-saccharide-solution supply pipe L11-2, a diluted-saccharide-solution supply pipe L11-4 that connects the diluted-saccharide-solution supply pipe L11-3 to the storage tank 25, and a diluted-saccharide-solution supply pipe L11-5 that connects the diluted-saccharide-solution supply pipe L11-3 to the first enzymatic saccharification tank 27.

A control valve V11 is provided on the diluted-saccharide-solution supply pipe L11-1, a control valve V12 is provided on the diluted-saccharide-solution supply pipe L11-2, a control valve V21 is provided on the diluted-saccharide-solution supply pipe L11-4, and a control valve V22 is provided on the diluted-saccharide-solution supply pipe L11-5. The control valve V11 controls an amount of the first saccharide solution 62 discharged from the second enzymatic saccharification tank (C6) 33, and the control valve V12 controls an amount of the second saccharide solution 64 discharged from the second enzymatic saccharification tank (C5) 34. Furthermore, the control valve V21 controls the diluted saccharide solution 37 supplied to the storage tank 25, and the control valve V22 controls the diluted saccharide solution 37 supplied to the first enzymatic saccharification tank 27.

Therefore, the diluted saccharide solution 37 produced in the cellulosic biomass saccharifying unit 16 can be supplied to one of or both of the storage tank 25 and the first enzymatic saccharification tank 27 via the diluted-saccharide-solution supply pipe L11. That is, in a regulation stage before the carbohydrate-based material 21 is saccharified and the saccharide solution 22 is produced in the saccharide-solution controlling unit 15A, for example, in the present embodiment, a stage where carbohydrate-based material 21 is ground or pulverized by the grinding machine 23 and the pulverizer 24 and transferred to the storage tank 25 or a stage where the first enzymatic saccharification tank 27 performs saccharification (including a stage before the saccharification in a batch system), the diluted saccharide solution 37 produced by the cellulosic biomass saccharifying unit 16 is supplied. The saccharide concentration of the saccharide solution 22 obtained from the carbohydrate-based material 21 can be thereby set to a predetermined saccharide concentration (15 mass %, for example). Furthermore, by using the first saccharide solution 62 and the second saccharide solution 64 as the diluted solution used when saccharifying the carbohydrate-based material 21, the consumption of water for dilution can be suppressed. Therefore, it is possible to reduce the cost required to produce the saccharide solution 22.

Conventionally, when the carbohydrate-based material 21 is saccharified and the saccharide solution 22 is produced, half of components contained in the carbohydrate-based material 21 are starch and the saccharide concentration of the saccharide solution obtained when the carbohydrate-based material 21 is saccharified as it is 20% to 60%. When a high-concentration saccharide solution is used when producing alcohol, the saccharide-solution producing apparatus is put in a higher alcohol concentration condition as fermentation proceeds and microorganism become extinct. Therefore, it is impossible to use the high-concentration saccharide solution as it is. Therefore, it is necessary to dilute the carbohydrate-based material 21 with water and to produce the saccharide solution 22 when the carbohydrate-based material 21 is saccharified and the saccharide solution 22 is produced. On the other hand, when the biomass material 35 is saccharified and the saccharide solution 22 is produced, the concentration of the hydrothermally treated biomass (the solid residual fraction 39 and the hydrothermally discharged fraction 40) discharged from the biomass material 35 is low. Therefore, it is necessary to increase the concentration of the hydrothermally treated biomass (the solid residual fraction 39 and the hydrothermally discharged fraction 40) or to increase addition amounts of the first enzyme 61 and the second enzyme 63 by which these enzymes are added to the hydrothermally treated biomass (the solid residual fraction 39 and the hydrothermally discharged fraction 40), to increase saccharide concentrations of the obtained first saccharide solution 62 and the second saccharide solution 64, and to produce the saccharide solution 22.

On the other hand, according to the saccharide-solution producing apparatus 11A of the present embodiment, by using the first saccharide solution 62 and the second saccharide solution 64 as the diluted solution used when saccharifying the carbohydrate-based material 21, it is possible to reduce the saccharide concentration of the saccharide solution obtained from the carbohydrate-based material 21 and to produce the saccharide solution 22 at the predetermined saccharide concentration (15 mass %, for example) without increasing the saccharide concentration of the first saccharide solution 62 and the second saccharide solution 64. Furthermore, it is possible to suppress the consumption of the water used when saccharifying the carbohydrate-based material 21. It is thereby possible to obtain the saccharide solution 22 at the preferable concentration for alcohol fermentation or the like, and to reduce the cost required to produce the saccharide solution 22.

In the present embodiment, the first saccharide solution 62 and the second saccharide solution 64 obtained by saccharifying the solid residual fraction 39 and the hydrothermally discharged fraction 40 that are discharged from the hydrothermal decomposition device 32A are supplied, as the diluted saccharide solution 37, to one of or both of the storage tank 25 and the first enzymatic saccharification tank 27. However, the present invention is not limited thereto. Alternatively, either the first saccharide solution 62 or the second saccharide solution 64 can be supplied, as the diluted saccharide solution 37, to one of or both of the storage tank 25 and the first enzymatic saccharification tank 27.

After the saccharide solution 22 at the predetermined concentration is produced in the first enzymatic saccharification tank 27, the saccharide solution 22 that is an alcohol fermentation material is supplied to the alcohol fermentation tank 12 by way of a saccharide-solution supply line L12.

The alcohol fermentation tank 12 is a fermentation tank in which microorganism are added to the saccharide solution 22 to cause fermentation and in which alcohol (an organic material) is produced. The alcohol fermentation tank 12 performs a fermentation treatment by added microorganism 65 under predetermined conditions.

An alcohol fermentation liquid 71 obtained as a result of the alcohol fermentation is supplied to the distillation column 13 by way of a fermentation-liquid supply line L13 and distilled in the distillation column 13. Distillate 72 obtained as a result of distillation is passed through an alcohol supply line L14, purified by a refining device such as a dehydrator 73, supplied to the alcohol tank 14, and stored in the alcohol tank 14. Alcohol 74 such as ethanol that is a product is supplied from this alcohol tank 14 by way of a supply line L15 as needed.

A residue 75 in the alcohol fermentation tank 12 is discharged by way of a yeast-residue discharge line L21. Furthermore, a distillation residue 76 in the distillation column 13 is discharged by way of a distillation-residue discharge line L**21**, passed through a separator **77**, a dryer **78**, and a refrigerator **79**, and discharged as distilled residue **800**.

When the alcohol **74** is produced by the use of the alcohol producing system **10**A, when a production volume of the alcohol **74** is 100000 kl/year, then that of the carbohydrate-based material **21** can be set to 90000 kl/year and that of the biomass material **35** can be set to 10000 kl/year. As compared with a case of producing the alcohol **74** using only the carbohydrate-based material **21**, the alcohol **74** can be produced in the same amount as the conventional amount while suppressing the annual use of the carbohydrate-based material **21**.

As described above, according to the alcohol producing system **10**A that includes the saccharide-solution producing apparatus **11**A of the present embodiment, the diluted saccharide solution **37** derived from the biomass material **35** produced in the cellulosic biomass saccharifying unit **16** is supplied to one of or both of the storage tank **25** and the first enzymatic saccharification tank **27** via the diluted-saccharide-solution supply line L**11**, and the diluted saccharide solution **37** is mixed in the regulation stage before producing the saccharide solution **22** from the carbohydrate-based material **21**. It is thereby possible to improve production efficiency of the saccharide solution **22** obtained from the carbohydrate-based material **21**, to set the saccharide concentration of the saccharide solution **22** to the predetermined saccharide concentration (15 mass %, for example), and to reduce the cost required to produce the saccharide solution **22**. As a result, by producing the saccharide solution **22** at the predetermined saccharide concentration by the use of the diluted saccharide solution **37** derived from the biomass material **35** when the saccharide solution **22** derived from the carbohydrate-based material **21** is controlled, it is possible to improve producing efficiency for producing the alcohol **74** and to reduce the cost required to produce the alcohol **74**.

In the present embodiment, examples of the carbohydrate-based material **21** include cereal crops such as corn, rice, wheat, barley, and cassava. However, the present invention is not particularly limited thereto.

For example, when corns **81** are used as the carbohydrate-based material **21**, both the carbohydrate-based material **21** such as kernels and the cellulosic biomass material **35** such as leaves, stalks and cobs of the corns are obtained from the corns **81**. Therefore, it is possible to produce the saccharide solution **22** further efficiently. FIG. **4** is an example of a case where the corns **81** are applied as the material. As shown in FIG. **4**, both the carbohydrate-based material **21** such as kernels **81***a* and the cellulosic biomass material **35** such as leaves, stalks and cobs of the corns **81***b* are obtained from the corns **81**. Accordingly, the kernels **81***a* and the like can be used as the carbohydrate-based material **21**, and the leaves, stalks, and cobs of the corns **81***b* can be used as the cellulosic biomass material **35**. According to the saccharide-solution producing apparatus **11**A of the present embodiment, it is possible to obtain the saccharide solution **22** further efficiently and to improve efficiency of producing an organic material such as the alcohol **74** without generating waste from one material such as the corns **81**.

In the present embodiment, the case of fermenting alcohol that is the organic material by the use of the saccharide solution **22** has been described as the fermentation system. However, the fermentation system using the saccharide solution according to the present embodiment is not limited to this system. While it has been described by way of example that the alcohol (ethanol, methanol or the like) that is the organic material is obtained by the fermentation treatment, the present invention is not limited to these examples. Alternatively, a petroleum substitute that is a chemical-product material or amino acid that is a food or feedstuff material other than the alcohol can be obtained by the fermentation apparatus.

Examples of chemical products obtained from the saccharide solution **22** include LPG, automobile fuel, aircraft jet fuel, heating oil, diesel oil, various types of heavy oil, fuel gas, naphtha, ethylene glycol that is a naphtha decomposed material, ethanol, amine, lactic acid, alcohol ethoxylate, vinyl chloride polymer, aluminum alkyl, PVA, acetic acid vinyl emulsion, polystyrene, polyethylene, polypropylene, polycarbonate, MMA resin, nylon, and polyester. Therefore, the diluted saccharide solution **37** derived from biomass can be efficiently used as substitutes for chemical products derived from crude oil that is exhaustible fuel and materials for producing the substitutes.

Second Embodiment

A saccharide-solution producing apparatus according to a second embodiment of the present invention is described with reference to the drawings. FIG. **5** is a schematic diagram of an alcohol producing system including the saccharide-solution producing apparatus according to the second embodiment of the present invention. Because the configuration of the saccharide-solution producing apparatus according to the present embodiment is identical to that of the alcohol producing system including the saccharide-solution producing apparatus according to the first embodiment of the present invention shown in FIG. **1**, members identical to those according to the first embodiment are denoted by like reference signs and redundant explanations thereof will be omitted.

As shown in FIG. **5**, an alcohol producing system **10**B includes a saccharide-solution producing apparatus **11**B according to the present embodiment, the alcohol fermentation tank **12**, the distillation column **13**, and the alcohol tank **14**.

The saccharide-solution producing apparatus **11**B according to the present embodiment uses molasses **83** as a saccharification material obtained from the carbohydrate-based material **21** of the saccharide-solution producing apparatus **11**A according to the first embodiment of the present invention shown in FIG. **1**. That is, the saccharide-solution producing apparatus **11**B according to the present embodiment includes a saccharide-solution controlling unit **15**B and the cellulosic biomass saccharifying unit **16**.

The saccharide-solution controlling unit **15**B produces the saccharide solution **22** from the molasses **83**. The saccharide-solution controlling unit **15**B includes the storage tank **25** and a saccharide-concentration controlling tank **84**. The molasses **83** is discharged or squeezed from the carbohydrate-based material **21**. The molasses **83** obtained from the carbohydrate-based material **21** is stored in the storage tank **25**. A saccharide concentration of the molasses **83** stored in the storage tank **25** is controlled by the saccharide-concentration controlling tank **84**.

Because the cellulosic biomass saccharifying unit **16** is identical to that in the saccharide-solution producing apparatus **11** according to the first embodiment of the present invention described above, explanations thereof will be omitted.

The diluted saccharide solution **37** produced in the cellulosic biomass saccharifying unit **16** is supplied to one of or both of the storage tank **25** and the saccharide-concentration controlling tank **84** via the diluted-saccharide-solution supply pipe L**11**. It is thereby possible to mix the diluted saccharide solution **37** with the molasses **83** obtained from the carbohydrate-based material **21**. That is, in the saccharide-solution controlling unit **15**B, in the regulation stage before producing the saccharide solution **22** from the molasses **83** obtained from the carbohydrate-based material **21**, the diluted saccharide solution **37** produced in the cellulosic biomass saccharifying unit **16** is supplied to the molasses **83**.

The saccharide concentration of the molasses **83** obtained from the carbohydrate-based material **21** can be set to a predetermined saccharide concentration (15 mass %, for example). Furthermore, by using the first saccharide solution **62** and the second saccharide solution **64** as the diluted solution used when saccharifying the carbohydrate-based material **21**, the consumption of water for dilution can be suppressed. Therefore, it is possible to reduce the cost required to produce the saccharide solution **22**.

Thus, according to the saccharide-solution producing apparatus **11**B of the present embodiment, by using the first saccharide solution **62** and the second saccharide solution **64** as the diluted solution used when saccharifying the carbohydrate-based material **21**, it is possible to reduce the saccharide concentration of the molasses **83** obtained from the carbohydrate-based material **21** and to produce the saccharide solution **22** at the predetermined saccharide concentration (15 mass %, for example) without increasing the saccharide concentration of the first saccharide solution **62** and the second saccharide solution **64**. Furthermore, it is possible to suppress the consumption of the water used when producing the saccharide solution **22** from the molasses **83**. It is thereby possible to obtain the saccharide solution **22** at the preferable concentration for alcohol fermentation or the like, and to reduce the cost required to produce the saccharide solution **22**.

Therefore, according to the alcohol producing system **10**B that includes the saccharide-solution producing apparatus **11**B of the present embodiment, the saccharide solution **22** at the predetermined saccharide concentration is produced using the diluted saccharide solution **37** derived from the biomass material **35** when the molasses **83** derived from the carbohydrate-based material **21** is controlled. It is thereby possible to improve the producing efficiency for producing the alcohol **74** and to reduce the cost required to produce the alcohol **74**.

In the present embodiment, while the case of using molasses as the saccharification material obtained from the carbohydrate-based material **21** has been explained, the present invention is not limited thereto. It suffices that the saccharification material is a material such as sugarcane or sugar beet that is obtained by being discharged or squeezed from the carbohydrate-based material **21**.

For example, when sugarcane is used as the material, molasses is obtained as the carbohydrate-based material **21** from the sugarcane, and the cellulosic biomass material **35** such as a residue (bagasse) obtained when squeezing saccharides from leaves or the sugarcane is obtained. Therefore, it is possible to produce the saccharide solution **22** further efficiently. FIG. **6** is an example of a case where sugarcane is applied as the material. As shown in FIG. **6**, both the molasses **83** that is the carbohydrate-based material **21** and the cellulosic biomass material **35** such as leaves and bagasse **85**B are obtained from sugarcane **85**. As a result, the molasses **83** can be used as the carbohydrate-based material **21**, and the leaves, the bagasse **85**B and the like can be used as the cellulosic biomass material **35**. Therefore, according to the saccharide-solution producing apparatus **11**B of the present embodiment, it is possible to obtain the saccharide solution **22** further efficiently and to improve the efficiency of producing the organic material such as the alcohol **74** without generating waste from one material.

REFERENCE SIGNS LIST

10A, **10**B alcohol producing system
11A, **11**B saccharide-solution producing apparatus
12 alcohol fermentation tank
13 distillation column
14 alcohol tank
15A, **15**B saccharide-solution controlling unit
16 cellulosic biomass saccharifying unit
21 carbohydrate-based material
22 saccharide solution
23, **31** grinding machine
24 pulverizer
25 storage tank
26 cooker
27 first enzymatic saccharification tank
32A, **32**B hydrothermal decomposition device
33 second enzymatic saccharification tank (C**6**)
34 second enzymatic saccharification tank (C**5**)
35 cellulosic biomass material (biomass material)
37 diluted saccharide solution
38 ground biomass material
39 solid residual fraction
40 hydrothermally treated fraction
41, **51** biomass supply device
42, **52** reaction device
43 biomass discharge device
44 screw unit
45 pressurized hot water
47 dehydration liquid
48 pressurized nitrogen (N_2)
49 temperature jacket
53 fixed agitating unit
61 first enzyme (cellulase)
62 first saccharide solution
63 second enzyme
64 second saccharide solution
65 microbe
71 alcohol fermentation liquid
72 distillate
73 dehydrator
74 alcohol
75 residue
76 distillation residue
77 separator
78 dryer
79 refrigerator
80 distilled residue
81 corn
83 molasses
84 saccharide-concentration controlling tank
85 sugarcane
L**11**, L**11-1** to L**11-5** diluted-saccharide-solution supply pipe
V**11**, V**12**, V**21**, V**22** control valve
V**31** to V**35** differential pressure control valve (ON-OFF valve)

The invention claimed is:

1. A saccharide-solution producing method comprising:
obtaining, from a single starting material, a cellulosic biomass material comprising a cellulose component, a

lignin component and a hemicellulose component, and a carbohydrate-based material comprising starch as a main component;

hydrothermally decomposing the cellulosic biomass material to produce a solid residual fraction and a hydrothermally discharged fraction, the solid residual fraction containing the cellulose component and the hydrothermally discharged fraction containing the lignin component and the hemicellulose component;

saccharifying at least one of the solid residual fraction and the hydrothermally discharged fraction with one or more enzymes to produce a diluted saccharide solution having a concentration of 0.1 mass % to 15 mass %;

storing the carbohydrate-based material in a storage tank;

transferring the carbohydrate-based material from the storage tank to an enzymatic saccharification tank;

in the enzymatic saccharification tank, producing a starch-based saccharide solution from the carbohydrate-based material, the starch-based saccharide solution having a concentration higher than the diluted saccharide solution;

diluting the concentration of the starch-based saccharide solution with water to form a diluted starch-based saccharide solution;

supplying the diluted saccharide solution into the enzymatic saccharification tank containing the diluted starch-based saccharide solution, wherein the concentration of the diluted starch-based saccharide solution is decreased with the water and the diluted saccharide solution to produce a final saccharide solution having a predetermined concentration.

2. The saccharide-solution producing method according to claim **1**, wherein the saccharifying the at least one of the solid residual fraction and the hydrothermally discharged fraction includes any one or both of: 1) saccharifying the cellulose component with a first enzyme to produce a first diluted saccharide solution containing hexose; and 2) saccharifying the hemicellulose component with a second enzyme so to produce a second diluted saccharide solution containing pentose, wherein at least one of the first and second diluted saccharide solution produces the diluted saccharide solution.

3. A saccharide-solution producing method comprising:

obtaining, from a single starting material, a cellulosic biomass material comprising a cellulose component, a lignin component and a hemicellulose component, and molasses;

hydrothermally decomposing the cellulosic biomass material to produce a solid residual fraction and a hydrothermally discharged fraction, the solid residual fraction containing the cellulose component and the hydrothermally discharged fraction containing the lignin component and the hemicellulose component;

saccharifying at least one of the solid residual fraction and the hydrothermally discharged fraction with one or more enzymes to produce a diluted saccharide solution having a concentration of 0.1 mass % to 15 mass %;

storing the molasses in a storage tank;

transferring the molasses from the storage tank to a saccharide-concentration controlling tank;

in the saccharide-concentration controlling tank, producing a molasses-based saccharide solution from the molasses, the molasses-based saccharide solution having a concentration higher than that of the diluted saccharide solution;

diluting the concentration of the molasses-based saccharide solution with water to form a diluted molasses-based saccharide solution;

supplying the diluted saccharide solution into the saccharide-concentration controlling tank containing the diluted molasses-based saccharide solution, wherein the concentration of the diluted molasses-based saccharide solution is decreased with the water and the diluted saccharide solution to produce a final saccharide solution having a predetermined concentration.

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